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14. ABSTRACT
The most significant output of the AFOSR funded research at design advance is our first commercial product CircuitSpace. It was developed after studying large scale real world layout problems such as UAV layout and PCB layout. The study resulted in clearly defining the design workflow and identifying three opportunities: problem size, constrained layout and design reuse. The product successfully solves the issues of problem complexity resulting from large number of components, constraint intensive layout, and design reuse. It does so by hierarchically decomposing the problem into subproblems, solving the constrained layout problem at the subproblem level using domain heuristics and Extended Pattern Search algorithms and by using a hypergraph isomorphism based algorithm for placement reuse from already placed designs. CircuitSpace is a award winning product that is being successfully used by many customers.

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A DECOMPOSITION BASED APPROACH TO OPTIMAL LAYOUT OF COMPLEX SYSTEMS SUCH AS UAV'S AND SATELLITES

Contract Number : FA9550-05-C-0087

Principle Investigator: JAY McCORMACK

Significant work accomplished

Commercial Product

The most significant output of the AFOSR funded research at design advance is our first commercial product CircuitSpace™. The second version of CircuitSpace™ was released in 2nd quarter of 2007 and is being successfully used by our customers. The product has been well reviewed by industry experts and is gaining momentum in terms of sales.

Awards

CircuitSpace™ won the International Engineering Consortium 2006 Design Vision award given to the best new product in the electronic design industry.

Journal Papers

Aladahalli, C., Cagan, Jonathan; Shimada, Kenji, *Objective Function Effect Based Pattern Search - Theoretical Framework Inspired by 3D Component Layout*, ASME Journal of Mechanical Design, 2007, Vol: 129, pp 243-254.

Aladahalli, Chandankumar; Cagan, Jonathan; Shimada, Kenji, *Objective Function Effect Based Pattern Search - An Implementation for 3D Component Layout*, ASME Journal of Mechanical Design, 2007, Vol: 129, pp 255-265.

Funded Students

Lindsay Hanna, Constraint Solving in Stochastic Optimization Methods (5/10 expected)

Objectives and Goals

The objective of this STTR was to develop software tools to automatically layout complex electromechanical systems ranging from UAVs to Printed Circuit Boards. In particular, the goal was to automatically position components within the product container while satisfying constraints and optimizing product objectives. Since the number of components in these real world layout problems can be very large, a hierarchical subdivision approach was proposed and developed in this STTR. Two different domains, namely UAV/Aircraft layout and Printed Circuit Board layout were studied in this STTR. The main tasks were to understand the user workflow, identify significant opportunities and to propose and test solutions in both these domains and to commercialize product in PCB market.

Understand Design Workflow

Layout professionals in both the UAV and PCB domains were interview to capture respective workflows. The resultant worflows are shown in Figures 1 and 2 below.

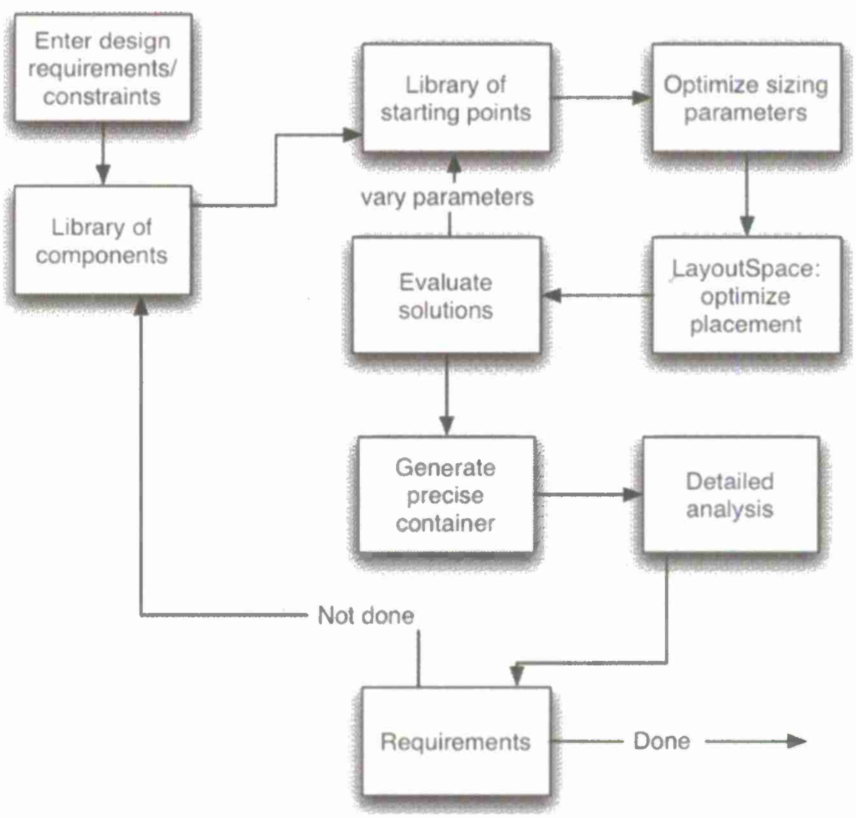


Figure 1: UAV early design workflow

A key aspect in early stage UAV design workflow was that 80% of the cost was locked in by the early stage design. The early stage design itself dealt with about 20 components which were subsystems in themselves. The workflow consisted of generating and testing numerous designs while being informed from the best of the previous designs. Previous designs were used as starting points and were varied to generate new designs. Constraints played a key role in the selection and placement of the early components.

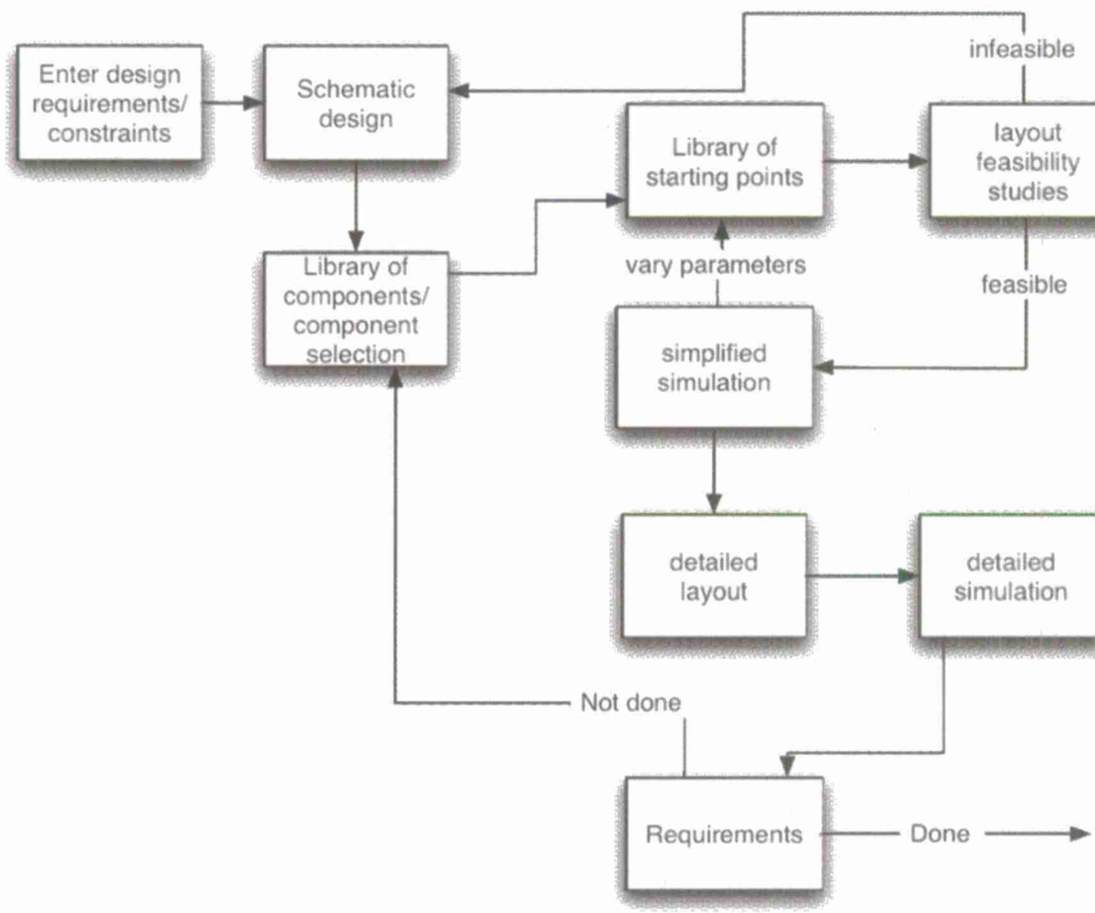


Figure 2: PCB design workflow

The PCB design workflow involves both early stage design with few components and detailed design with thousands of components. It is characterized by heavy design reuse especially in the detailed design stage. The design reuse is both within a design and across designs. The design cycle is very short with time to market being a key concern.

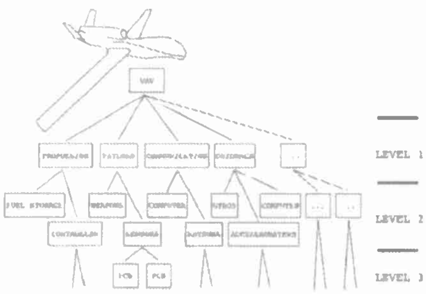
Identify opportunities

From the user interviews three opportunities were identified namely, the design invloved large number of components (in the order of thousands), the layout was constraint intensive and that there is a prominent scope for reuse of layout information from previous designs.

Solution Method and Results

Large number of components

The solution approach for dealing with a large number of components was to hierarchically decompose the problem into subproblems with orders of magnitude fewer components. These individual subproblems are now tractactable using existing layout algorithms like Extended Pattern Search. Once the subproblems are solved they are intergrated to generate a system solution. The integration sometimes involved solving a layout problem with the sub units. Figure 3 shows the decomposition based approch to solving problem complexity resulting from many components.



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TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 3: Decomposition based approach to deal with layout complexity

In UAV domain the problem can be subdivided into hierarchically into subsystems. In the PCB domain the components are subdivided into clusters of electrical functional units. Sub systems in a UAV design are easily identified, however in the PCB they have to be derived from electrical connectivity, schematic information and heuristics.

A tool was implemented to automatically subdivide the parts on a PCB into clusters of functional blocks by interpreting the schematic from which they were read. Next, a layout is generated for components in the cluster with respect to each other. The layout is performed by first identifying available space around the major component of the cluster. Available space can be restricted by an imposed boundary on the cluster and already placed components. The pattern search algorithm along with some domain heuristics is used to produce a layout solution for the involved components.

These clusters are extremely important in early stage PCB design since it is makes it easier to work with tens of clusters instead of thousands of parts. In UAV design sub systems are readily available in early stage and also 80% of the cost is determined there. Therefore, sub divison is not as critical in the early design process. However it is very useful in the later stages of design.

Constrained layout

In the early stage design there are typically a few components that are constrained. There constraints are usually more well defined than the design objectives along with their tradeoffs. A generalized constraint solving approach was used to solve the constrained problem. The approach is described in Figure 4.

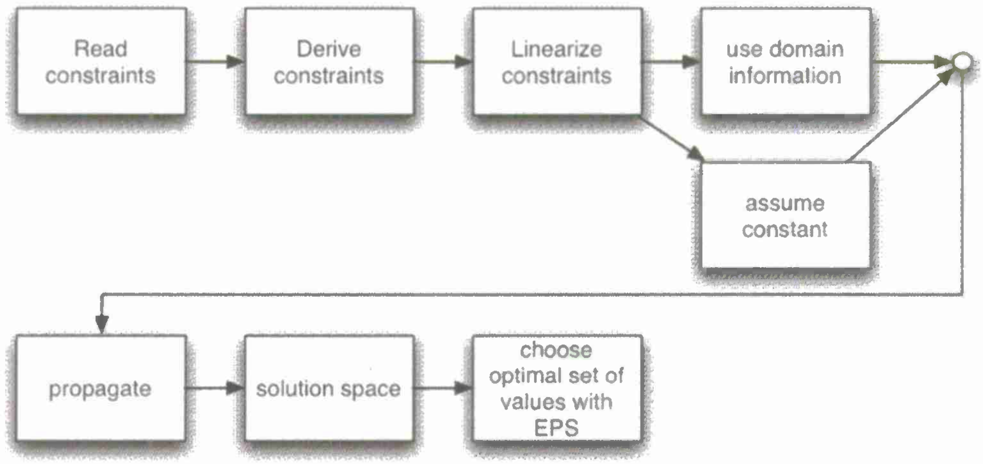

Figure 4: General constraint solution approach

A aircraft problem with constraints was modeled and solved. The problem is shown is Figure 5. The constraints included lateral distance constraint between front and rear wheels, small angle constraint, ground stability constraint, distance and height relationship constraint between main and tail wings, and CG location constraint.

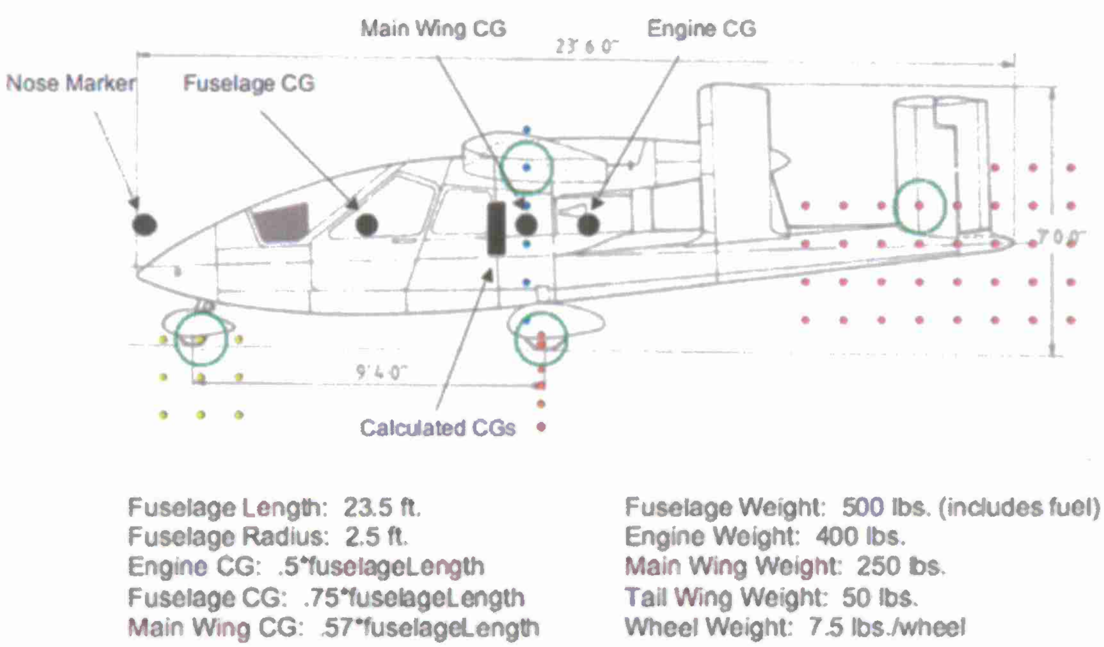

Figure 5: Example of a constrained aircraft layout problem.

PCB constraints included user given constraints such as length constraints, derived constraints such as orientation, relative positioning, and non intersection of connections constraints. Figure 6 shows how placement side of a part on the PCB is limited by the constraint that connections do not intersect.

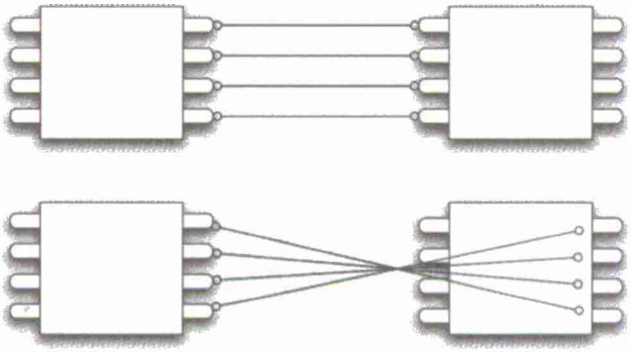

Figure 6: Side limitation due to non-intersecting connections constraint

Constraint aware automated layout is beneficial to both domains in early design. The constraint solver implemented for PCB domain benefits greatly by incorporating domain information and implied constraints enable simplification.Typically the constraint solution space is large space and feasible solutions are not difficult to find.

Design reuse

Design reuse has distinctly different applications in the two domains studied. It is however critically important to both design flows. It is found in both early and detailed design. Since the applications are different the algorithms required are also distinctly different.

In the UAV example design reuse consists of using previous work to build a starting point. A multitude of designs are generated from variations to this starting point and evaluated. Also elements of multiple previous designs are combined to generate new designs. The model used is a parametric and is built from parameter values that are taken from similar past designs. A statistical design of experiments based approach is useful in this context.

However, in PCB domain reuse consists of copy placement and routing information from sections of previous designs into a new design. Here it is necessary to establish the similarity of two sub circuits to correctly copy over placement information from one to another. A hypergraph isomorphism based approach was implemented to enable this. Figure 7 shows results of a design reuse where placement from a 40 part cluster from a previous design was applied to 24 similar clusters that were automatically detected by the hypergraph isomerism algorithm

Figure 7: Placement information reuse from previous design.